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On the Digestibility of Protein, Oil and Starch in *Penaeus orientalis**

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(East China Sea Fisheries Research Institute, Shanghai 200090)[1]

KEYWORDS *Penaeus orientalis*, protein, oil[2], starch, digestibility

Although some research has been done on the digestibility of protein and amino acids in *Penaeus orientalis* [3], this research has not yet dealt with changes in digestibility in different environments and under different conditions of growth, and no formal reports on the determination of the digestibility of oil and starch in this prawn have yet appeared. As *Penaeus orientalis* is an aquaculture species peculiar to China, further research on

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* This research was funded by the Shanghai Youth Scientific Foundation. Wang Suqin and Liu Zhongsong, students from the graduating class of 1990 of the Shanghai Aquaculture University, participated in the entirety of the experiment.

This manuscript was received in July of 1990 and revised in February of 1991.

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[1] Translator's Note: The title of the text can be translated more literally as "A Preliminary Investigation of the Digestibility of Protein, Oil and Starch in *Penaeus orientalis*." The name of the author's institute can also be translated more literally as "the Eastern Sea Aquatic Products Research Institute".

[2] Translator's Note: The characters *zhifang* translated in the original text as "oil" can be more precisely translated as "fat". In this translation, the text is followed, and *zhifang* is translated as "oil".

the digestive physiology of *Penaeus orientalis* has great significance for science as well as for aquaculture.

MATERIALS AND METHODS

1. Water and aquariums used in the experiments

[The water used in the experiments][1] was seawater, diluted to 8‰. Except for the temperature experiments, the water temperature in the other experiments was maintained without exception between 27°C and 30°C. Each glass aquarium had a capacity of 60 cm X 45 cm X 40 cm and held water of a volume of 55 cm X 45 cm X 30 cm. Each aquarium had a filter trough with a volume of 45 cm X 28 cm X 5 cm. The filter material consisted of acrylic cotton and crushed stones on whose surface a biomembrane had formed. The amount of water filtered daily was four to six times the volume of the aquarium.

2. Prawns used in the experiments These were taken from the Fengxian Marine Farm of this institute. After the prawns had been taken to the laboratory and fed on bait for two days, they were fed the appropriate experimental bait for the following seven days, and then their excrement was collected. In the same experimental area, in order to eliminate error caused by differences in body length, every

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[1] Translator's Note: Inference. In this translation, inferences are given in square brackets.

effort was made to use prawns of the same length for each experimental group, or to distribute the prawns in a homologous fashion.

3. Bait used in the experiment Table 1 shows the feed formulas used in investigating the digestibility of protein, oil and starch for different diet compositions. Of these formulas, Feed Formula No. III was used in investigating the effect of water temperature and body length on the digestibility of protein. Table 2 shows the feed formulas used in investigating the effect of [dietary] starch levels on the digestibility of protein. The starch used was raw starch from pure wheat.

The protein-free feed formula used in determining the level of autogenous excremental nitrogen was [composed of]: 30% α-starch, 40% dextrin, 10% fibre, 8.7% mineral preparation, 7% fish oil, 1.5% vitamins, 0.7% cohesive agent, 0.1% Cr_2O_3, and 2% attractant. Because the vitamins, cohesive agent and attractant all contained nitrogen, and for other reasons as well, the corresponding protein level in this feed formula was determined by conversion to be still as much as 3.39%.

Table 1 Feed formula used in the experiment of protein, oil and starch digestibility

a. 配方 / b. 原料(%)	I	II	III	IV	V	VI
c. 秘鲁鱼粉	37.8	49.5	61.2	68.0	84.6	99.2
d. 小麦粉	52.2	40.5	28.8	22.0	5.4	0
e. 维生素	1.0	1.0	1.0	1.0	1.0	0
f. 矿物质	8.2	8.2	8.2	8.2	8.2	0
g. 粘合剂	0.7	0.7	0.7	0.7	0.7	0.7
h. Cr_2O_3	0.1	0.1	0.1	0.1	0.1	0.1
i. 实测值 (%)						
j 蛋白质	34.06	38.88	43.29	48.59	53.75	59.71
k 脂肪	2.07	2.24	3.15	3.65	4.75	5.64
l 淀粉	40.45	27.70	24.17	20.00	12.71	0
m Cr_2O_3	0.11	0.13	0.12	0.11	0.12	0.09

Table 1 Feed formulas used in investigating the digestibility of protein, oil and starch[1]

a. Feed formula
b. Ingredients (%)
c. Milu fishmeal[2]
d. Wheat flour
e. Vitamins
f. Minerals
g. Cohesive agent
h. Cr_2O_3
i. Actual level determined (%)
j. Protein
k. Oil
l. Starch
m. Cr_2O_3

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[1] Translator's Note: In this text, the titles of tables and figures are translated only when the English title given in the text is awkward, or differs substantially from the text.

[2] Translator's Note: The characters for "Milu" can also mean Peru, so the fishmeal may be Peruvian fishmeal.

Table 2 Effect of feed formula used in the experiment of different starch level in diet on protein digestibility

b 原料(%) \ a. 配方	1	2	3	4	5	6
c. 秘鲁鱼粉	65	65	65	65	65	65
d. 精制淀粉	25	20	15	10	5	0
e. 纤维素	0	5	10	15	20	25
f. 维生素	1	1	1	1	1	1
g. 矿物质	8.2	8.2	8.2	8.2	8.2	8.2
h. 粘结剂	0.7	0.7	0.7	0.7	0.7	0.7
i. Cr_2O_3	0.1	0.1	0.1	0.1	0.1	0.1
j. 实测值						
k. 蛋白质	43.06	43.38	43.31	43.35	43.31	43.46
l. Cr_2O_3	0.11	0.10	0.10	0.11	0.11	0.10

Table 2 Feed formulas used in investigating the effect of different [dietary] starch levels on protein digestibility

a. Feed formula
b. Ingredients (%)
c. Milu fishmeal
d. Refined starch
e. Fibre
f. Vitamins
g. Mineral matter
h. Cohesive agent
i. Cr_2O_3
j. Actual level determined (%)
k. Protein
l. Cr_2O_3

4. Procedures and collection of excrement During the experiment, bait was fed twice a day at 8:00 and 15:30. The amount of bait fed daily was 3% of body weight. Two hours after the bait was fed, the leftover bait was siphoned off, and after 6 hours, the collection of excrement began. Collection was done once every hour.

5. Determination and calculation In references [1, 5, 3] the formulas for calculating digestibility in all determinations are:

Apparent digestibility
$$x=100\left(1-\frac{C_{rf}\cdot N_w}{C_{rw}\cdot N_f}\right)\ldots \tag{1}$$

Actual digestibility
$$y=100\left(1-\frac{\frac{C_{rf}}{C_{rw}}\cdot N_w-\frac{C_{fu}}{C_{wu}}}{N_f}\right)\ldots \tag{2}$$

In the formulas:

C_{rf} is the chromium level in feed,

C_{rw} is the chromium level in excrement,

C_{rfu} is the chromium level in protein-free feed,

C_{rwu} is the chromium level in excrement of prawns that have eaten protein-free feed,

N_f is the protein level in feed,

N_w is the protein level in excrement, and

N_{wu} is the protein level in excrement after consumption of protein-free feed.

RESULTS

1. Apparent and actual digestibility of protein From Table 3, it can be seen that when the proportion of Milu fishmeal [in the feed] increased and that of wheat starch decreased, the beginning of change in the digestibility of protein in *Penaeus orientalis* was not at all conspicuous. However, when the protein level in the feed changed from 43% to 60%, the digestibility increased from 79.58% to 92.24%. When a correlation analysis of the last four feed formulas was made using the protein level [in the feed] as the independent variable and the digestibility of protein as the dependent variable, the results indicated a correlation coefficient (r) of 0.99. It can be held that within the above interval of change, an excellent linear relationship exists between the protein level in the feed and the digestibility of protein.

The results of determination for the protein-free feed were [as follows]: the chromium level was 0.09% in the feed and 0.41% in the excrement, while the protein level in the excrement was 6.90%, and the apparent protein level in the feed was 3.39%. When the actual digestibility of protein was calculated according to Formula (2), the digestion rates for Feed Formula I to Feed Formula VI were 85.09%, 83.02%, 83.24%, 86.36%, 90.45% and 94.26% respectively. Figure 1 clearly shows the changes in apparent and actual protein digestibility for different protein levels in the feed.

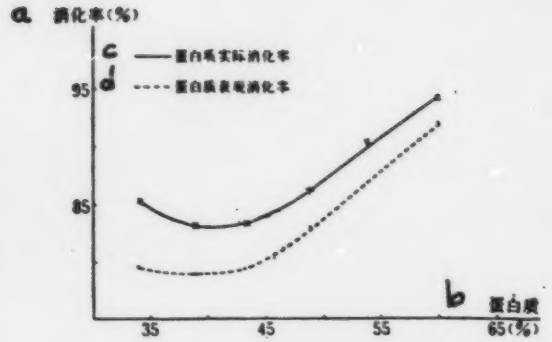
Table 3 Digestibility of protein, oil and starch

b. 测定值(%) \ a. 配方	I	II	III	IV	V	VI
c. 蛋白质和脂肪的消化率试验						
d. 粪含铬量	0.47	0.46	0.44	0.45	0.52	0.52
e. 粪蛋白量	27.45	29.49	32.11	32.65	33.01	26.04
f. 粪含脂量	1.36	1.00	1.32	1.02	1.20	1.43
g. 蛋白质消化率	79.70	79.29	79.58	83.09	86.23	92.24
h. 脂肪的消化率	83.67	89.13	90.42	91.42	94.34	95.49
i. 淀粉消化率试验						
j. 粪含铬量	0.41	0.29	0.53	0.57	0.49	
k. 粪淀粉量	6.33	2.66	1.59	0.80	0.67	
l. 淀粉消化率	95.61	95.74	96.58	99.25	98.74	

a. Feed formula
b. Level determined(%)
c. Experiment on the digestibility of protein and oil
d. Chromium level in excrement
e. Protein level in excrement
f. Oil level in excrement
g. Digestibility of protein
h. Digestibility of oil
i. Experiment on the digestibility of starch
j. Chromium level in excrement
k. Starch level in excrement
l. Digestibility of starch

2. Effect of change in starch levels in the feed on the digestibility of protein From Table 4, it can be seen that aside from a jump in the digestibility of protein when the starch level in the feed drops from 25% to 20%, there is a notable linear relationship between the starch levels (x) in Formulas 2 to 6 and the corresponding digestibility of protein (y). The coefficient r is 0.94. This shows that for feeds with different starch levels, even if the protein levels are the same, the digestibility of protein in *Penaeus orientalis* will be different.

3. Effect of body length and water temperature on the digestibility of protein It can be seen from Table 5 that when body length is greater than 10.5 cm, the digestibility of protein increases significantly. When the body length is between 8 cm and 10.5 cm, the digestibility of protein stays at almost the same level. When water temperature is 30°C, digestibility is at its optimum level, and when water temperature is 35°C, digestibility is at the lowest level, being only 67.58%. When the water temperature is lower than 30°C, digestibility increases as water temperature rises. It can also be seen from Table 5 that the great drop in protein digestibility is due to the significant increase in protein levels in the excrement.



附 图 中国对虾对蛋白质的实际消化率和表观消化率

Attached fig. Actual and apparent digestibility of protein in the diet of *Penaeus orientalis*

a. Digestibility (%)

b. Protein

c. Actual digestibility of protein

d. Apparent digestibility of protein

Table 4 Effect of different starch levels in diet on protein digestibility

b 测定值(%) \ a 配方	1	2	3	4	5	6
c 粪含铬量	0.38	0.43	0.45	0.41	0.36	0.35
d 粪蛋白量	37.17	28.34	27.30	21.68	17.19	16.37
e 蛋白质消化率	74.58	85.37	85.51	86.05	88.31	89.62

a. Feed formula

b. Level determined (%)

c. Chromium level in excrement

d. Protein level in excrement

e. Digestibility of protein

Table 5 Effect of body length and temperature on protein digestibility

a 不同体长试验				
c 测定(%) \ b 体长(cm)	8.0	9.0	10.5	11.5
d 粪含铬量	0.40	0.37	0.42	0.45
e 粪蛋白量	34.86	33.45	36.47	33.45
f 蛋白质消化率	75.22	74.73	75.92	79.16
g 不同温度试验				
i 测定(%) \ h 温度(℃)	20	25	30	35
j 粪含铬量	0.34	0.35	0.36	0.47
k 粪蛋白量	30.21	29.66	31.52	54.96
l 蛋白质消化率	75.36	76.51	81.01	67.58

a. Experiments with different body lengths
b. Body length (cm)
c. Level determined (%)
d. Chromium level in excrement
e. Protein level in excrement
f. Digestibility of protein
g. Experiments at different temperatures
h. Temperature (^{o}C)
i. [Level] determined (%)
j. Chromium level in excrement
k. Protein level in excrement
l. Digestibility of protein

4. Digestibility of oil and starch It can be seen from Table 3 that the digestibility of oil, like [that of] protein, increases with the rise in the oil level in the feed. The digestibility of starch is inversely related to the starch level in the feed. At starch levels higher than 25% (Table 3), the digestibility is relatively low. At starch levels lower than 25%, the digestibility is relatively high, at least 98.5%.

DISCUSSION

1. Digestibility of protein at different protein levels According to the results of previous research[4], there are only two possibilities that present themselves as the chief reason for the change in the apparent digestibility of protein: the effect of [different] starch levels [in the feed], or the result of an increase in the proportion of autogenous nitrogen in the excrement caused by a drop in protein levels [in the feed].

The results of the research on *Penaeus orientalis* [described] in this paper show that for protein levels in the feed between 43% and 60%, the digestibility [of protein] increases with the protein level. The positive correlation is very conspicuous. This is similar to what is observed in yellowtail and rainbow trout[7]. Comparison of the actual and apparent digestibilities of protein shows them to be practically identical in how they change. On the basis of this, we can infer that for *Penaeus orientalis*, the increase in the proportion of autogenous excremental nitrogen is

not the chief reason for the change in the apparent digestibility of protein.

2. Effect of starch on protein digestibility From the results in Table 4, it can be further confirmed that the effect of starch on the digestibility of protein is significant. It can be held that the change in the digestibility of protein in *Penaeus orientalis* is affected by the starch level in the feed. In addition, it can be seen from a comparison of the results in Tables 3 and 4 that when the starch level in the feed exceeds 20%, the result is a distinct falling-off point in the digestibility of protein. The results of both experiments are consistent on this point. Therefore, in preparing pellet feed for *Penaeus orientalis*, the starch level should generally be lower than 20%.

3. Effect of body length and water temperature on protein digestibility When body length is greater than 10.5 cm, the digestibility of protein in *Penaeus orientalis* begins to rise significantly. This body length is representative of just the very period when [growth] for *Penaeus orientalis* changes from growth in body length to growth in body weight. Growth in body weight requires acceleration of the internal accumulation of protein. This change in the digestibility of protein is the very result of the physiological need of *Penaeus orientalis* to accelerate protein accumulation. As for the effect of water temperature, 30°C is the optimum temperature for protein digestibility. It is also the most suitable temperature for the

growth of *Penaeus orientalis*. At 20°C to 30°C, water temperature and digestibility have a positive correlation; at 30°C to 35°C, they have an inverse correlation. When water temperature reaches 35°C, protein digestibility also decreases sharply. The results of Table 5 suggest that perhaps it is the decrease in enzyme activity that causes poor digestion. The significant increase in excremental protein levels also illustrates this point.

4. Digestibility of oil and starch The digestibility of oil in *Penaeus orientalis* has more or less the same characteristics of change as the digestibility of protein: that is, as the oil level in the feed decreases and the starch level increases, the digestibility of oil decreases correspondingly. However, the digestibility of starch in *Penaeus orientalis* presents the opposite situation, being in inverse correlation with the starch level. From this, it can be seen that *Penaeus orientalis* has the same digestive physiological characteristics as carnivorous fish.

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